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ABSTRACT

Behaviorism cannot adequately explain language processing. A synthesis of the psycholinguistic and information processing approaches of cognitive psychology, however, can provide the basis for a speculative analysis of reading, if this synthesis is tempered by a perceptual learning theory of uncertainty reduction. Theorists of information processing have used models from computers, communication, and linguistics. Reduction of uncertainty theorists have developed two models of how information is processed, template matching and feature analysis. Template matching posits a preconceived notion of a letter, while feature analysis depends upon a series of binary decisions. Distributional and sequential redundancy reduces uncertainty in reading by limiting the possible positions letters and words can occupy. Physiologically, binary type operations selectively destroy sensory stimulation as they travel along the optic nerve. Current hypotheses about short and long term memory deal with their structure, function, and capacity. The uncertainty reduction model, in which the reader's task is to reduce the gamut of alternatives so that the original semantic intent of the author can be reconstructed, possesses an explanatory capacity consistent with evidence regarding oral language development. Although one need not accept the pure mathematical foundations of uncertainty theory, a computer paradigm is helpful in resolving the seemingly contradictory positions of the psycholinguists and information processing advocates. The ability to direct attention automatically and naturally between the graphophonic, syntactic, and semantic levels of a message links the two approaches. (JL)

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A Theory of Perceptual Learning: Uncertainty Reduction and Reading

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October 11, 1982

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A Theory of Perceptual Learning:
Uncertainty Reduction and Reading

Reading is a highly complex process. From an arbitrary set of graphic symbols, a reader is expected to reconstruct the original meaning intended by the author. In some instances, the recipient of the message is presumed to go well beyond the parameters established by the contriver to even deeper levels of understanding. Certainly, this intricate yet enormous undertaking involves a multitude of latent psychological factors. By necessity the interaction of these variables will determine to a great extent the relative success of any reading act.

It is the intent of this paper to speculate as to the nature of the reading process by delineating a theory of uncertainty reduction. This cognitively-based perceptual supposition differs markedly from the positions offered by associative learning camps. The latter tend to view learning in an additive sense, that is, as an accumulation of stimulus-response bonds and three-term contingencies. In sharp contrast, Gibson and Levin(1978) state:

> "Perceptual learning is not the adding on of anything. It is, rather, an increase of specificity of discrimination to stimulus input, an increase in differentiation of stimulus information. It is an extraction or 'pulling out' rather than adding on. The modification is in <u>what</u> is perceived."

It is the author's contention that the magnitude and viability of uncertainty reduction's departure from aggregative

learning theories constitutes a justification for further analysis and investigation.

The Limitations of Associationism

Currently educational psychology tends to be rather sharply divided between two primary schools of thought. These basic outlooks are commonly referred to as Behaviorism and Cognitivism. The majority of this paper will deal with the latter orientation. It would be both unfair and irresponsible to completely overlook the behavioral point of view, however, the author maintains that cognitive constructs offer considerably more explanatory power in regard to reading. For this reason the following discussion of behaviorism has been made purposely brief. As a result, the development of the position represents a necessary oversimplification.

Behavioral psychology is based principally on the works of B.F. Skinner, although it roots trace back as least as far as Thorndike(1913) and his Law of Effect. The behaviorist is concerned with empirical measurements of observable responses. This brand of psychology holds that the occurence of a behavior is contingent upon its consequences. Responses can be modified by the reinforcement that follows. The probability of the behavior being emitted at some future point in time depends on the nature of the reinforcement. It may serve to either strengthen or weaken the likelihood of occurence or to have no appreciable effect whatsoever. For example, in Skinnerian

terms, a written word represents a discriminative stimulus. When reading, the organism may emit an oral response in the presence of the S^D. This is followed by a reinforcing stimulus such as "good" or "no" which can be supplied by other individuals in the environment or which may occur within the organism itself. If the reader is accurate and is told so(or if the idenfication is internally positive) then he/she would be prone to respond in the same way when the same graphic stimuli is encountered subsequently. An incorrect response, accompanied by a reinforcer which signals the error, should cause the child to try an alternative response in the presence of the discriminative stimuli upon its next presentation. Each of these situations represents a 3-term contingency. It is highly unlikely that each of a stock of thousands of words known at sight received the kind of reinforcement and shaping required by the behavioral point of view for assimilation.

Basically behavioral psychology is more suited to the maintenance of a desired response rather than to the initial learning of the behavior(Bandura, 1965). This is particularly true in reading where complex patterns of behavior must be internalized. Much more is involved than the overt and quantifiable products which follow reading tasks. There are processes at work which mediate between the graphic stimuli and the productive reconstruction of the message within the organism. Since these processes are as yet not subject to

direct observation, they are largely ignored by behaviorists. To forego the existence of an intervening set of variables is simply unrealistic. Failing to investigate the nature of these variables makes the behavioral outlook narrow in scope.

Particularly in relation to language, behaviorism falls noticeably short in its explicative range. It cannot account for the infinite number of novel sentences which can be both generated and decoded by the native speaker. According to Dale(1976), language learning is not reducible to mere imitative behavior. Children utter things they have never heard or spoken before and this phenomena is certainly not restricted to beginning language users(Slobin, 1979). Adults continually construct unique syntactical patterns to express new semantic relationships. In addition, they, like children, find "new way to say old things" and "old ways to say new things"(Moskowitz, 1978).

This very sentence, although basically conforming to a simple syntactic pattern and using relatively familiar words, is most likely unique unto itself. It is largely improbable that the author was sufficiently reinforced for each of the constituent lexical items and structural elements in this exact pattern prior to the occasion of this writing. Language learning, while undeniably influenced by bonds which link stimuli and responses, appears to be too global an endeavor to be adequately accounted for by a cumulatively-oriented behavioral persuasion.

Cognitive Alternatives

Authorities, by and large, subscribe to a more comprehensive view of reading dynamics. Cognitive psychology attempts to explain all the previously discussed areas that behaviorism is either incapable or unwilling to address. Among those constructs upon which this psychology is founded are perception, developmental stages, structures of the intellect, category inclusion, generative theory, and information processing to name a few.

Even within the realm of Cognitive psychology, there exists a bona fide dichotomy of viewpoints concerning the nature of the reading process. The two primary factions are the Psycholinguistic(PL) and Information Processing(IP) groups. They differ mainly in the way reading growth is perceived. Those that adhere to the psycholinguistic point of view would suggest that the acquisition of reading proficiency follows a general to specific course of development. Advocates of the information processing perspective believe that just the opposite takes place. The PL approach represents a top-down model of reading while the IP approach constitutes a bottom-up theory. Several models have been proposed for each of these orientations(Goodman, 1970; Gough, 1972; LaBerge and Samuels, 1974; Ruddell, 1969).

While both the psycholinguistic and information processing models are feasible in their own right, neither is

fully capable of explaining the reading phenomena. Each is highly developed in the aspects which support their basic viewpoint but tend to treat the strengths of the other only superficially. The PL model, for example, is primarily concerned with specifying the nature of syntactic and semantic components of language. It virtually ignores the featural aspect. On the other hand, the IP model comprehensively addresses the issues of basic pattern recognition and routing of information but it does not adequately depict the interactive language variables as they exist in long term memory.

For the purposes of this speculative analysis of reading, I have found it useful to attempt to synthesize these two positions. In this way I feel the explanatory capability exceeds either of the positions taken in isolation. This integration is tempered by the perceptual learning theory of uncertainty reduction as described by Gibson and Levin (1978), Smith(1978), and Gibson (1969).

Perceptual Learning Theory

Perceptual learning theory is just one of several views regarding reading acquisition and performance(Gibson and Levin, 1978). This cognitive orientation assumes that learning is a process of reduction rather than as an amalgam of associations. In any perceptual or learning task the organism must deal with some degree of uncertainty regarding it. This uncertainty may stem from a variety of sources.

Most prominent among these are the physical characteristics of the array, the attentional processes and cognitive development of the perceiver, and the context within which the stimuli are presented. Before the stimulus can be accurately perceived, the range of possible alternatives must be sufficiently limited. Theoretically, when all of the perceiver's uncertainty has been eliminated, comprehension takes place.

This base of operations is the result of a synthesis of views from varying orientations and disciplines. Contributions have been made in such fields as perceptual and developmental psychology, mathematics, linguistics, cybernetics, and communication. Each has helped delineate and refine the theory towards a more realistic, empirical, and functional utility.

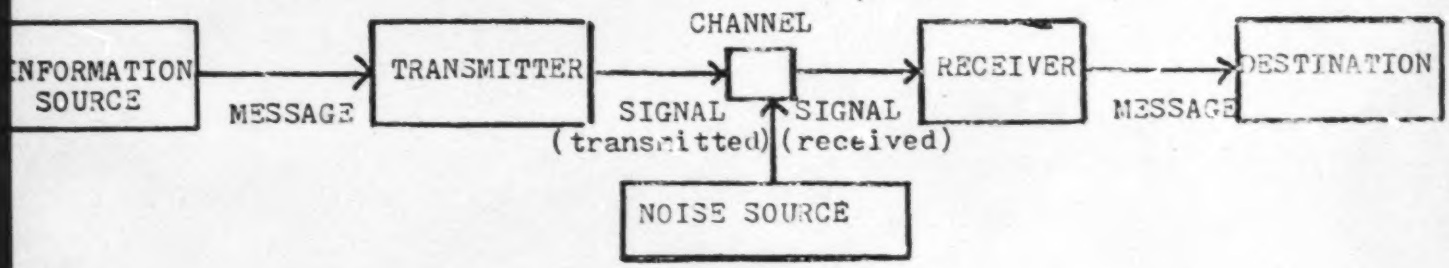
From a historical perspective, perceptual learning theory is a product of three trends in psychology(Gibson, 1969). The first, probabilistic cue learning, involved making inferences essentially like those made in gambling. These inferences are unconscious and emanate from the perceiver's prior experience with the stimuli's frequency of occurence. A transactionalist view of perception, the second school of thought, maintained that these unconscious inferences were greatly tempered by the personal, internal world of each individual. Gibson(1969) states:

> "The individual lives in his own world of assumptions, which may be illusory, and which determines his perceptions. The subjective evaluation of impinging stimulation is thought to be directed not only by previous experiences leading to weighted assumptions but also by personal values and attitudes."

The third trend placed greater emphasis on the constructive, judgmental, and problem-solving nature of perception. This view holds that as the individual develops, his cognitive structures of past experience serve to mediate perception. While differences exist between the major theorists of this trend, their fundamental assumptions involve the nature of intellectual structures.

Psychologically, the main perceptual concern has been in how information is processed. In this vein, some theorists have introduced the mathematical concepts of binary operations to explain how alternatives confronting the decision-maker are delimited(Smith, 1978). Generally these perspectives utilize a computer paradigm of sorts to explain the mediating processes involved in perception. For the most part, computer simulation of human intelligence has been dismissed on the grounds that the brain is not dependent on anything like a linear sequential program(Hubel, 1979). However, the notion of flow charting is still alive and encouraged in terms of positing as to the nature of the reading process(Just and Carpenter, 1980). While the theories involving information processing structures such as sensory store and long and short term memories have not been proven in the empirical sense, when viewed in tandem with the general principles of uncertainty reduction, they appear to be useful for describing reading in a broad perceptual sense(Resnick and Beck, 1975).

Additional major contributions to contemporary perceptual theories and their relationship to reading have been made by Communication(information) and Linguistic model-builders. Shannon and Weaver(1959) proposed the following communication system:

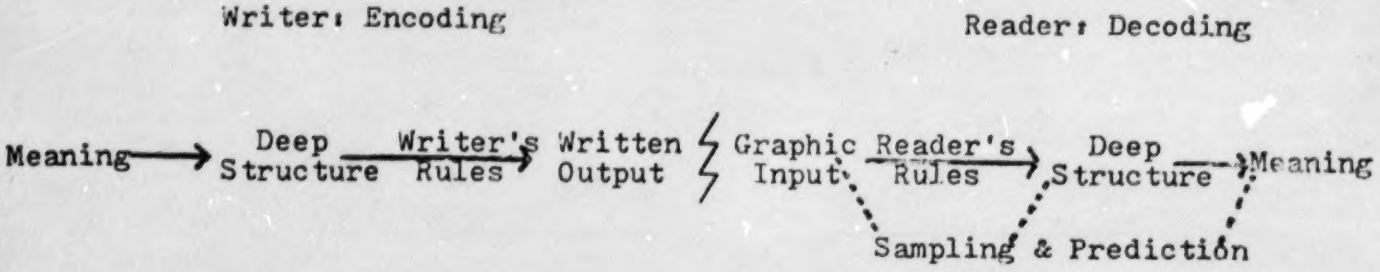


Here a "message" is encoded, transmitted along a channel of limited capacity where it is subject to interference, and received. Along this pathway a multitude of factors can cause the received message to differ from the message the source had intended to transmit. These inhibiting factors are termed "noise." For a communication system to be efficient, the signal-to-noise ratio must be large. Pierce (1972) maintains that one extremely useful outcome of Shannon's original work(1948) is his introduction of a means to measure the commodity to be transmitted. This measure constitutes a unit of uncertainty or choice and is referred to as a bit. As will be seen in later sections of this paper, this binary notion can be meaningful in terms of the way linguistic information is processed.

Shannon was also interested in the powerful body of probabilistic theory and its relationship to language. Specifically he dealt with Markov processes wherein the probability of a particular event changes depending on the events that just preceded it. While the advent of functional computer translation led to the development of an improved grammar system, it ultimately resulted in the demise of probabilistic notions concerning linguistic communication (Pierce, 1972). Chomsky(1957) rejected these proposals largely on statistical grounds. He maintained that although a statistical process could generate a sentence, the likelihood that it will occur has nothing to do with its grammaticality. Rubenstein(1973) lamented the dismissal of probability factors, contending that they play a large part in determining the deep structure of a sentence. He suggests that the receiver of a message "delimits the set of concepts that may follow and assigns probabilities to them." This idea of predictions extends to ambiguous sentences as well.

Nonetheless, Chomsky's transformational-generative grammar revolutionized the field of linguistics. He attempted to demonstrate that a message could exist on more than one level. The semantic notion of a message resided within the contriver at the deep structure level. Through a series of syntactical transformations, the message took a surface structure representation. Chomsky's work primarily addressed

the syntactic bridge between deep and surface structures. His concern was in developing a system that adequately describes how a basic semantic notion could assume a virtually infinite number of surface forms. Goodman(1970) utilized Chomsky's model as a means of explaining how linguistic messages are understood. This model appears below:

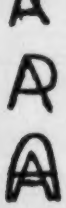


According to the model, effective communication both begins and ends with meaning. Basically the writer has a semantic notion which he submits to his inherent knowledge of linguistic rules so that a written representation evolves. The reader, confronted by the graphic stimuli which constitutes a relative degree of uncertainty, subjects it to his own syntactic and semantic knowledge from a process of sampling and prediction. The decoding process involves reducing the number of alternatives at the deep structure level. The end product is a reconstruction of the author's original message. All of the psycholinguistic models which have evolved since Goodman's original work have maintained those structures originally posited by Chomsky.

The Reduction of Uncertainty

Reduction of uncertainty theorists tend to view the human as a sophisticated processor of linguistic input. The mind is seen as a complicated and organized system of interrelated structures whose proper functionings collectively result in efficient perceptual strategies. Researchers have sought to determine the basic manner in which the input is interpreted. Thus far two theories, template matching and feature analysis, have been proposed.

The template matching supposition holds that the information processor has a preconceived notion of a letter by which all comparisons are made. He would, by definition, place this prototype "over" each letter as it exists between the sensory store and memories to see if it matches. This process seems inefficient and has been largely discarded for the distinctive feature position by the majority of researchers. It should be noted at this point that the evidence for both positions is considerably less than conclusive. This viewpoint has difficulty in accommodating the wide variety of forms which a letter can take from cursive to manuscript to individual writing styles. Anderson(1975) suggests that:



"Some A templates fit some R's better than some A's."

The feature position, in theory, seems much more feasible. Gibson and Levin(1978) state that coded items, like words and written symbols share common features that serve to distinguish that set from other sets. But these sets can be further subdivided by alternatives within them. They go on to say:

> "In order to identify something as unique, we must know its alternatives--what it might have been, but isn't quite. Things come in finite sets, and there are feature contrasts within the set that are shared in different degrees by the members of the set."

These distinctive features, as they are known, allocate an object to a particular category with respect to a set of alternatives. The bundle of attributes which define an object(feature list) must be invariant over a number of irrelevant or noncritical transformations(Jakobson, 1972). With respect to letter recognition, several studies have been undertaken to determine just exactly what constitutes a distinctive feature(Gibson, 1965; Dunn-Rankin, 1978). To date, it is still largely unknown and is believed to be as much as function of the individual receiver as any possible physical characteristic of the visual array. Smith (1978) feels that distinctive features defy verbal description and fall into the realm of implicit understandings. Whatever the case, it is clear that readers must learn to attend to the most productive and economical cues while disregarding irrelevant(noise) ones. Of utmost importance

to the theory of uncertainty reduction is that through a series of binary decisions a stimulus can be, in essence, accurately identified. Jakobson(1972) states:

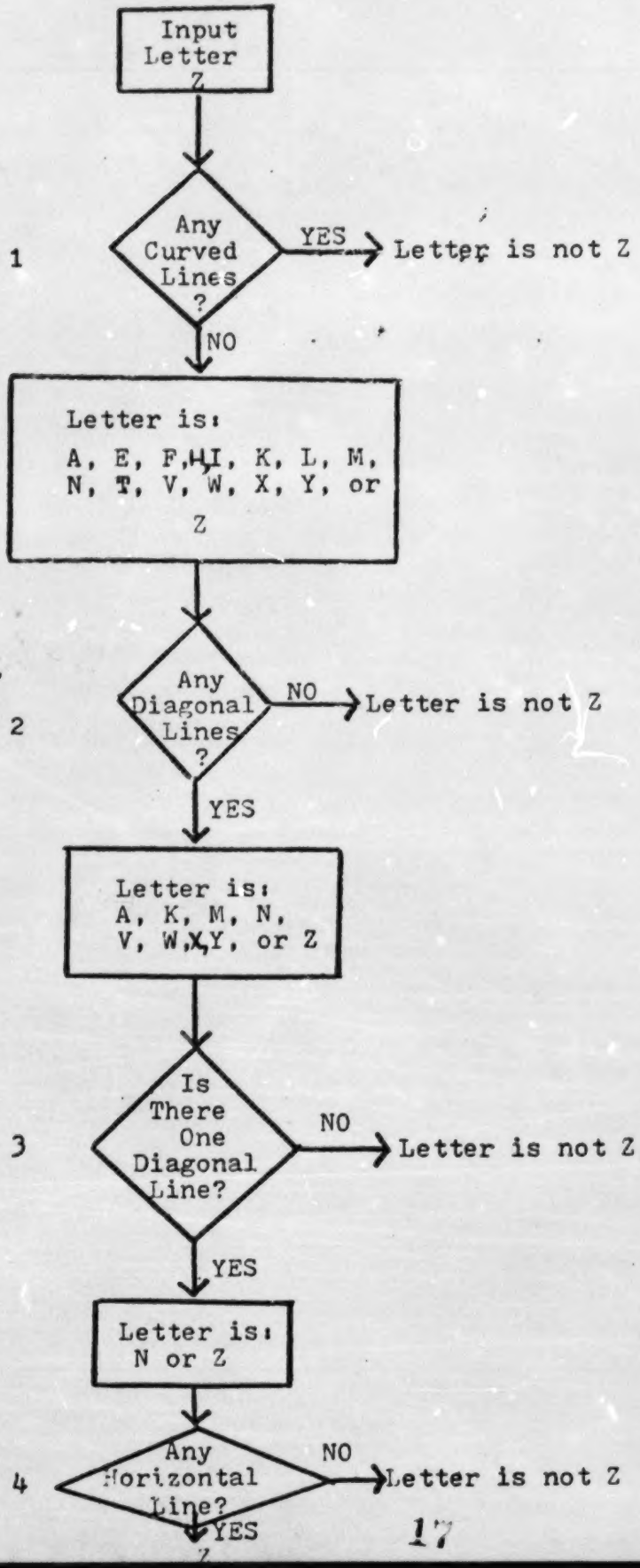
> "Every single constituent of any linguistic system is built on an opposition of two logical contradictories: the presence of an attribute("markedness") in contraposition to its absence("unmarkedness"). The entire network of language displays a hierarchical arrangement that within each level of the system follows the same dichotomous principle of marked terms superposed on the corresponding unmarked terms. And second, the continual, all-embracing, purposeful interplay of invariants and variations proves to be an essential, innermost property of language at each of its levels."

A case for the distinctive feature argument is demonstrated by Neisser's visual search task(Tarpy and Mayer, 1978):

Find the letter Z in this list	Find the letter Z in this list
ODUGOR	IVMXEW
OCDUGO	EWVMIX
COOGRD	EXWMVI
OUGCDR	IXEMWV
URDGOO	VXWEMI
GRUQDO	MXVEWI
DUZGRO	XVWMEI
UCGROD	MWXVIE
DORCGU	VIMEXW
ODOCGU	EXVWIM
CGUROQ	VWMIEX
OCDURO	VMWIEX
UOCGOD	XVWMEI
RGOCOU	WXVEMI
GRUDOO	XMEWIV
GODUCQ	MXIVEW
OCURDO	VEWMIX
DUCOOG	EMVXWI
CGRDOU	IVWMEX
UDRCOQ	IEVMWX
GOCORU	WVZMXE
GOOUCD	XEMIWV
GDOUOC	WXIMEV
URDCGO	EMWIVX
GODROC	IVEMXW

Notice that locating the "Z" in the first column is considerably faster than in the second column. It is assumed that

FEATURE ANALYSIS
(BINARY PROCESSING)



(Loftus and Loftus, 1974)

FEATURE ANALYSIS
(Continued)

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Possible Number of Alternatives = 26

Decision	Eliminates	Number Remaining
1.- No Curved Lines	B, C, D, G, J, O, P, Q, R, S, U (11)	15 or 2^4 apx.
2.- Diagonal Lines	E, F, H, I, L, T (6)	9 or 2^3 apx.
3.- One Diagonal Line	A, K, M, V, W, X, Y (7)	2 or 2^1
4.- A Horizontal Line	N (1)	1 or 2^0

CONCLUSIONS

For a letter to be a "Z" it must have:

No Curved Lines

At Least One Diagonal Line

Only One Diagonal Line

A Horizontal Line

In order to reduce the alternatives to a set of one, a total of four decisions are theoretically required. In this example the identification of the "Z" was made after the remaining possibilities had been sufficiently delimited. The perception is contingent on knowing the set of invariant rules(attributes) that describe the "Z" and only the "Z".

For a model of reading to have high utility, it must deal with units considerably beyond individual letters. Smith(1978) proposes the following example at the word level. Assume that the first letter of a word was a "q". The amount of uncertainty regarding the next letter is 2^0 or 1 because only the letter "u" follows "q" in English. For the next position, only four possibilities are acceptable. Consequently, the "a", "e", "i", and "o" uncertainty measure is 2^2 or 4. The next letter would involve four bits of information(roughly) to account for the dozen or so alternatives. He states:

> "in general the uncertainty of any letter goes down the more other letters in the word are known, irrespective of order. Because of constraints in the spelling patterns of English--due in part to the way words are pronounced--there is slightly more uncertainty at the beginning of a word than at the end, with slightly less in the middle."

There are limits on the possible position letters and words can occupy. These constraints are imposed by the rules of orthography, syntax, and semantics. When information is available from more than one source, uncertainty is more easily reduced because the number of alternatives will

tend to be constrained. This characteristic of communication is known as redundancy and is of two basic types.

The first, distributional redundancy, refers to the fact that not all letters or words in English have an equal probability of occurence. When every alternative has an equal chance of occurring, uncertainty will be at its greatest point. The additional source of information that alternatives are not equally probable reduces the uncertainty of the set of possibilities as a whole. The letter "e", for example, occurs 40 times more frequently than "z" does. This knowledge becomes a factor in lessening uncertainty because one can expect to find more 'e's".

The second type of redundancy exists when the probability of a letter or word occurring is constrained by the presence of surrounding letters or words in the same sequence. This is known as sequential redundancy. The previously cited example of "q - u - ____" is indicative of sequential redundancy. Smith suggests than the probability that the letter "H" will follow "T" in English words is not one in 26 (the case when all letters had an equal chance of occurring in any position) nor about one in 17(taking distributional redundancy into account), but about one in 8("R", "H", or a vowel). Therefore 3 bits of uncertainty exist for any letter that follows "T" in English. Orthographic redundancy involves distributional and sequential redundancy

for letters within words, while grammatical and semantic redundancy are primarily sequential redundancies between words.

In the following example, notice how the choices are constrained, and therefore represent a reduction of uncertainty.

Tom is the best player on our baseball team.

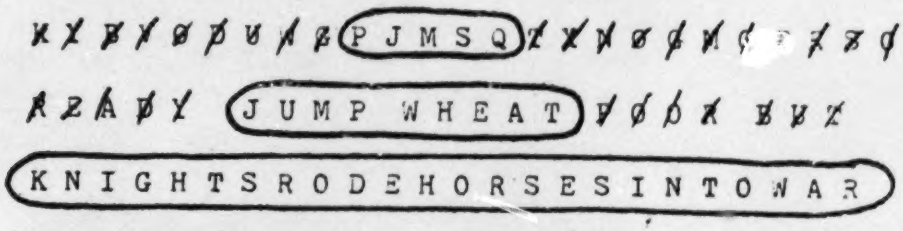
In the field he plays _____ base.

Syntactically, the alternatives are constrained by the basic sentence pattern. The choice must in some way modify the word "base". The most probable part of speech here is an adjective. This is confirmed by a semantic analysis. In baseball, there are only 4 bases and home is usually given the special designation "plate". Besides, "catcher" is a specific name for the player who fields this position. With 4 alternatives, our choice is constrained to 2^2 or two bits. If we eliminate homeplate on semantic grounds, then only 3 alternatives remain. Further let's assume that the first letter of the unknown stimulus is an "s". Since the only semantically acceptable choice that begins with an "s" is the word "second", our uncertainty is reduced to 2^0 or one. At this point it takes 0 bits of information to make the correct identification. By definition, comprehension is said to have occurred.

Where does all of this fit in physiologically? Visual information is initially received in the form of light rays impinging on the eye's surface. These images are transformed into neural impulses by the light sensitive retina. From here the neural energy is carried along the optic nerve past six points of interchange, until it arrives at the occipital lobe at the base of the brain(Stent, 1972). Along this journey to the primary visual area, sensory stimulation is selectively destroyed by means of several binary type operations. Thus the information is reduced to manageable proportions. From the occipital lobe the impulse is relayed to the angular gyrus, which associates the visual form of the word with the corresponding auditory pattern in Wernicke's area which is believed to play a major role in comprehension(Geschwind, 1979).

Limited by the current state of our technology, we are forced to speculate as to the information processing system of the brain. In the presence of a graphic stimulus, it is hypothesized that an image is formed and held in a structure known as the sensory store or register. Here the icon will persist for approximately one second. A common belief is that the sensory store is capable of holding roughly 25 bits of information. Smith(1978) refers to the experiments of Cattell as demonstrating that this is dependent on the probability and uncertainty of the letters that are presented. As evidence he offers a tachistoscopic perceptual task

involving random letters, unrelated words, and meaningful phrases. An example of this would be as follows:



It can be seen that random letters, due to a lack of constraints, require more visual attention and result in a general decrease in capacity. Merely positioning the letters to form words, even if they are unrelated to each other, increases the number of letters that can be recognized(approximately two words or 10 to 12 letters). Meaningful phrases result in the greatest degree of perception(four or five words and 25 letters) due to redundancies.

Images in the sensory store are quickly replaced by information from the next fixation point. This is known as masking. Retrieval of sensorily stored perception may involve making regressions. From the sensory store, the input is transferred to the next major component of the system.

This hypothetical structure is most commonly referred to as short term memory. At this juncture in the system 7 $\pm$ 2 bits of information are thought to endure for nearly 12 seconds although some estimates go as high as 20 seconds. Regardless, this data base represents what is at the forefront of your mind; what you are attending to and operating upon. This is where the individual lodges the traces of what is read

while attempting to make sense of the next few words. This primary or working memory is amenable to rehearsal of the input. Maintaining the data in this buffer enhances the likelihood that the concept can register in the long term memory. This is the procedure one follows in trying to commit a telephone number to memory long enough that the sequence can be recalled for the purposes of dialing. Retrieval is generally easy unless the information is not acted upon within the designated time. This precludes the possibility of subsequent retention (Gibson and Levin, 1978).

The final step is the integration of the perceptual information with existing structures held in long term memory. It is generally believed that it takes a minimum of five seconds to input the LTM. There is no guarantee that once situated in the LTM that the concepts can be accessed. This depends largely on the mode of original entry (i.e., novelty, vividness, and recency) and the nature of the retrieval cue. An entry mode or retrieval cue of high magnitude is likely to augment the probability of recall.

The capacity of the long term memory is theoretically infinite. Many psychologists feel that once information has gotten into the LTM it is never lost. It is the inadequacy of the retrieval cue or entry mode that prevents the memory from reaching a level of conscious awareness. The length of time that data can be stored and subsequently accessed remains

unknown although it is frequently the case when memories believed to be long lost unexpectedly come to the surface (Hebb, 1958).

A current trend in reading research involves specifying the hierarchical arrangement of conceptual understandings in the LTM and how these operate within the processing system (Just and Carpenter, 1980). At best these suppositions are promising, although highly speculative. Crick(1979) comments on these hypotheses in the following statement:

> "The basic difficulty is that psychology attempts to treat the brain as a black box. The experimenter studies the inputs and outputs and tries from the results to deduce the structure and operation of the inside of the box. The difficulty with the black-box approach is that unless the box is inherently very simple a stage is soon reached where several rival theories all explain the observed results equally well."

Uncertainty Reduction and Reading: A Broad Perspective

How does preceding discussion relate specifically to reading? Basically we must view uncertainty reduction in a broad sense. The notion that efficient perception represents a limitation of alternatives rather than an accumulation of S-R bonds is particularly useful and viable. In any reading situation there exists an unspecified degree of uncertainty regarding the visual stimuli. The reader's task is to reduce the gamut of alternatives so that the original semantic intent of the author can be reconstructed. To do so requires efficient decision-making based on the redundancy which exists between cueing systems and within

the individual. This necessitates a principle of economy in which sampling minimal language cues promotes automatic information processing.

Certainly the explanatory capacity of this uncertainty model is consistent with evidence regarding oral language development. Several authors(Dale, 1976; Goodman, 1970; Keyser, 1973; Postal, 1973; and Slobin, 1979) maintain that acquisition is a rule-governed enterprise. They would suggest that the child samples the wide range of auditory cues in the environment attempting to identify structural invariants. He/she makes predictions about "things and people and places and events" (Gibson and Levin, 1978). These predictions are either confirmed or rejected. In this way the multiple number of alternatives become reduced. The child is able to abstract the complex set of invariant rules that comprise the language system. As these rules become internalized and subsequently automaticized, the child's ability to anticipate the flow and content of the message increases dramatically. This theoretically accounts for the phenomenal language growth characteristically observed in children between the ages of two and five (Moskowitz, 1978).

This idea of successively approximating(to borrow some behavioral terminology) inoreasingly complex language forms holds for reading as well. Both graphic and oral messages share essentially the same language base. Consequently, the the decoding of a written message is subject to a similar,

but certainly not identical process of uncertainty reduction. What differs is the manner in which the cues are presented, sampled, and processed in the brain.

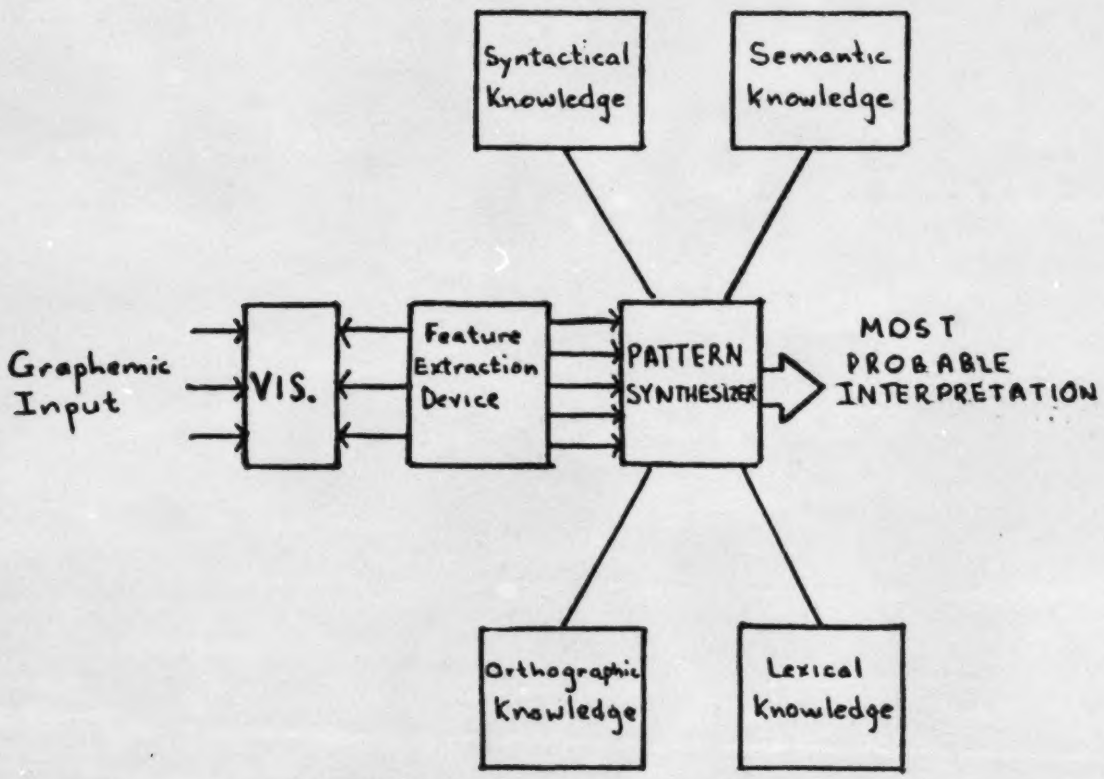
Continuing in this general sense, it is not necessary that one accept the pure mathematical foundations of uncertainty theory. The precision for which it opts by means of binary operations and probability constructs may only be an artifact of an analogue processing system of which it is just a part. Recent data suggests that the brain has the capacity to interpret stimulus information in both series and parallel(Just and Carpenter, 1980). Crick(1979) discusses the popular tendency to compare the brain with a computer:

> "In a computer information is processed at a rapid pulse rate and serially. In the brain the rate is much lower, but the information can be handled on millions of channels in parallel. The components of a modern computer are very reliable, but removing one or two of them can upset an entire computation. In comparison the neurons of the brain are somewhat unreliable, but the deletion of quite a few of them is unlikely to lead to any appreciable difference in behavior. A computer works on a strict binary code. The brains seems to rely on less precise methods of signaling."

He goes on to indicate that the brain is capable of performing much greater adaptation and that although it is rather poor at involved calculations, it is able to recognize patterns in ways "that no contemporary computer can begin to approach."

Still a computer paradigm is helpful in resolving the seemingly contradictory positions of the Psycholinguists and Information Processing advocates. Rumelhart(1976) has proposed a computer theory based on interactive stages and

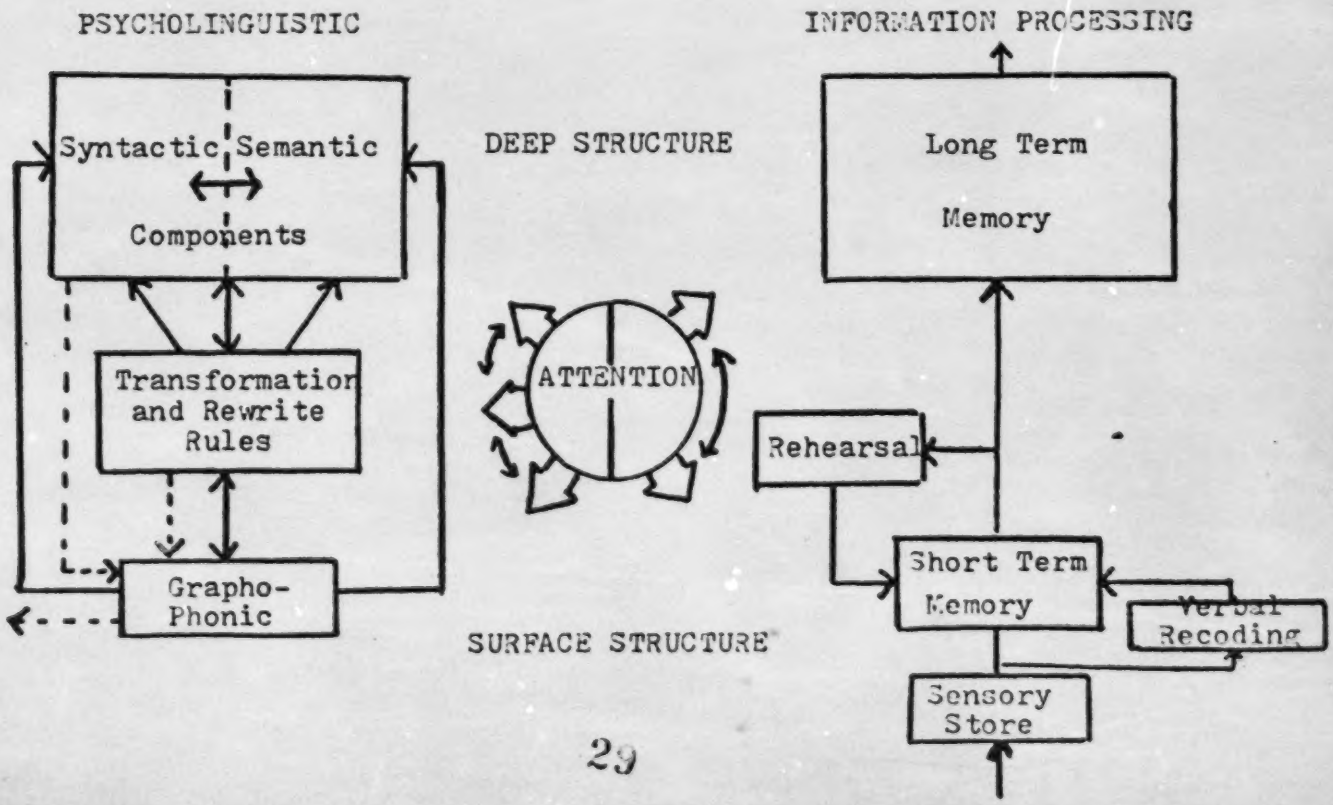
whose most unique quality is that it allows for both top-down and bottom-up processing. It predicts that information is integrated at the pattern synthesizer. The reader can assume features and proceed with meaning first and then move to verification of distinctive feature and letter and word codes. In addition, the reader can progress serially through the system by beginning with visual information and later extracting meaning. Just and Carpenter(1980) have used gaze durations to confirm the ability of the human system to accommodate both top-down and bottom-up processing. Rumelhart's model appears below:



Within this model, attentional processes serve a critical function. As a last step, we should examine their role.

The Role of Attention

When reading, shifts in attention are necessary to extract the most productive cues. At certain instances the significant information resides in the surface structure, while at other times the reader must access non-visual modes of reducing uncertainty. Proficient readers process graphic language at an automatic level and their attention is predominantly directed at the structural implications of the message. Mature readers must be seen as having developed a sophisticated information processing system. Central to this system is the ability to direct attention automatically and naturally between the graphophonic, syntactic, and semantic levels of a message. This resolve between the IP school of thought(LaBerge and Samuels, 1974; Samuels, 1977) and the PL position is shown below:



learning theory and its implications for reading. Subject matter for this topic was selected from several fields of study. It was the author's intent to synthesize those positions which were relevant in helping to explain the complex psychological processes involved in reading-related behavior.

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